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(54) IMPROVEMENTS IN OR RELATING TO LUMINOUS DISCHARGE DISPLAY DEVICES

(71) We, SIEMENS AKTIENGESELLSCHAFT, a German Company, of Berlin and Munich, German Federal Republic, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a luminous discharge display device in which a gas-filled sealed envelope contains a cathode, a luminescent screen electrode, and an insulating plate having a regular array of perforations forming image points of a gas discharge cell matrix. The proposed display device is of particular significance in relation to all forms of optical-electronic image reproduction, as for example television display devices and data displays, either in monochrome or in colour.

The German Patent Specification No. 2,213,153 describes a display panel with a gas discharge cell matrix in which intersection points are formed between two sets of parallel-wire electrodes disposed at right angles to one another, to define so-called scanning cells or display cells. Whereas for image display, the individual scanning cells, in the context of a bistable mode of operation, constitute direct illumination or image points in the relative gas discharge colour, if the discharge intensity is increased they can generate ultra-violet radiation which is then used in the ensuing display cells which contain a phosphorescent material to produce one of two different phosphorescent colours.

The drawback of this known arrangement is that the bistable mode of operation prevents the reproduction of images in grey tones or a conventional colour structure based upon the three primary colours. In addition, there is the fact that the ultraviolet light which is produced as a secondary radiation cannot be easily focussed and directed to selectively excite a specific phosphorescent point, and furthermore, the intensity obtainable is too low to compare satisfactorily with the level of picture brilliance which has become commonly acceptable in television image reproduction.

One object of the present invention is to provide a device which overcomes the indicated difficulties and drawbacks, yet enables a simple mode of operation to be employed, and requires a lower operating voltage than known devices.

The invention consists in a luminous discharge display device in which a gas-filled sealed envelope contains a common flow cathode, a luminescent screen electrode, and an insulating plate located between, and parallel to, said common cathode and said screen electrode and having a regular array of perforations forming individual image points of a gas discharge cell matrix, said plate serving as a carrier for two excitation electrode structures, one being an auxiliary anode structure and said cathode and said auxiliary anode electrode structure being on one side of said plate and mutually spaced at a distance adequate to permit normal glow discharge conditions for the particular gas and pressure, the electrode formed on or carried by the other side of the plate being a control electrode structure forming individual elements each associated with a respective one, or a respective group, of said perforations, said luminescent screen electrode being spaced from said control electrode structure by a distance significantly less than that between said cathode and auxiliary anode structure.

Thus, electrons produced in an auxiliary glow discharge which is controlled in row fashion, move towards the auxiliary anode, and are controlled in point fashion to determine the individual intensity by a correspondingly divided control electrode, are then in an ensuing, separate, special high field-strength discharge interval, accelerated towards a continuous screen electrode to produce the displayed image. Because of the small electrode separation, selected in ac-

cordance with the Paschen-type of discharge characteristic, it is possible to avoid with certainty any danger of the uncontrolled production of a gas discharge, and the division produced by the perforation matrix structure, facilitates reproduction of well-defined image points, whilst with the use of a triode system of control, correspondingly differentiated brilliance is easily obtained.

The perforated insulating plate may be of glass, ceramic or a synthetic resin material having an adequately low vapour pressure, and serves to effectively divide the overall discharge space into an auxiliary gas discharge space and an electron acceleration space in such a fashion that the gas discharge extends in the form of separate beams through the perforations of the plate.

The auxiliary gas discharge space is designed for the gas and gas pressure that are used, so as to correspond with the Paschen discharge characteristic, and will for example measure approximately 1 cm., and the electron acceleration space will be substantially shorter than 1 cm, i.e. only about 1/10 the length of the auxiliary gas discharge space. The transmission coefficient of the perforation matrix is chosen in excess of 20%, whilst the number of holes for a monochrome television image reproduction screen will be about 5×10^5, or for a colour television screen, about 1.5×10^6.

In one embodiment the perforated plate carries a set of mutually parallel electrode conductor paths on each side, the conductor paths on one side being perpendicular to the conductor paths on the other side.

Advantageously, the conductor paths will be produced using conventional techniques as for example printing, vapour deposition, or photographic processes, and is formed at the perforations to exhibit corresponding openings, or may pass around the peripheries of the individual perforations in the form of two split paths.

In a preferred embodiment which is particularly simple to manufacture, the conductor paths on each side of the perforated plate consist of parallel wires where colour reproduction is concerned, to take account of the fact that there will be three times the number of image points, the number of one of the types of conductor paths will be correspondingly increased by a factor of three. It is particularly advantageous to multiply the row conductor paths of the auxiliary anode structure, because otherwise at least three separate intermediate stores would be required for the individual colour signals, when using such devices.

Advantageously the luminscent display device is operated by applying a constant voltage of a few hundred volts, relative to the cathode potential, in succession to the individual conductor paths of the auxiliary anode structure, and by applying to the screen electrode a constant positive potential of a few thousand volts relative to the cathode potential, whilst the control electrode has applied a d.c. bias voltage on which there is superimposed the relevant control signal, in particular video signals, the voltages being applied simultaneously to the control electrode structure with the help of an intermediate store for each individual conductor path.

In a further advantageous embodiment which is designed to increase the image brilliance obtainable by utilising a storage effect, the video signal is applied by means of at least one intermediate store, each including a planar transistor, a modified design of the electrodes thus far described being used with control electrodes which are not electrically connected, but divided into separate points, and two additional electrodes constituted by mutually intersecting electrode elements serving as row and column electrodes.

Advantageously, in this further embodiment, the elements of the auxiliary anode structure are, for example, electrically connected with one another to form a continuous electrode surface, and at the rear side of the plate a corresponding number of intersections formed by two sets of mutually insulated parallel conductor paths is applied, to serve as row and column conductor paths.

In this kind of embodiment, it is then possible to provide adjacent each intersection a planar transistor formed in such a fashion that a lateral stub of the relevant row conductor path forms its source, the relevant column conductor path disposed perpendicularly thereto forms its gate, and an insulated metal ring about the associated perforations forms its drain, the semi-conductor material itself being applied in large-area fashion. It is of particular advantage to apply the semi-conductor material by vapour deposition and the material will therefore be constituted by substances which are suitable for this kind of process, as for example Zns, CdS, CdSe or Te.

For reasons of safety, the transistor matrix is covered with an insulating protective layer of, for example, SiO, SiO_2 or the like.

The invention will now be described with reference to the drawings, in which:—

Figure 1 is a schematic perspective exploded view of one exemplary embodiment, showing an insulated perforation matrix serving as a carrier for electrode structures, indicating the spatial relationships of the electrodes, including the cathode and the screen electrode and the electrical connections, but excluding those parts not essential to an understanding of the invention;

Figure 2 is a graph illustrating the discharge characteristics of a number of commercial gases in accordance with the Pas-

chen law; reproduced from the text-book "Gaseous Conduction", by I. D. Cobine, published by Dover Publications Inc., N.Y. 1957, pages 164—165; and

Figure 3, is a schematic perspective view of one alternative exemplary embodiment in which an insulated perforation matrix has metal-rimmed holes forming control electrodes, and showing the mutually perpendicular intersecting row and column electrodes for transistors which are incorporated at each intersection.

In the embodiment shown in Figure 1 an insulating perforated plate 1, referred to as the perforation matrix, is made of quartz, glass, ceramic or a synthetic resin material having an adequately low vapour pressure, the matrix containing a plurality of regularly disposed holes 2. Along each row of these holes there extends an electrode structure in the form of an applied conductor path 3, serving in this example as respective auxiliary anodes. The conductor paths 3 are applied to the substrate by printing, vapour deposition, or by a photographic process, for example. At each hole 2, the relevant conductor path passes around the periphery of the opening and then continues in the form of a narrow conductor path. On the other face of the perforation matrix, the conductor paths 4 are provided as column electrodes extending perpendicular to the row electrodes, to define the individual image points, these being defined in the same fashion as the electrodes 3. In addition, there is a solid cathode 5, which is arranged at an adequately large distance for a glow discharge, bearing in mind the Paschen type of discharge characteristic which is required, this cathode forming one of the two electrodes 3 and 5 which define the auxiliary gas discharge interval. On the remote side there is a screen electrode 6. When an individual row is driven by selectively raising the potential on the associated conductor path, a gas discharge is struck only to this row, and is initially maintained because the other row electrodes have a floating potential, or are maintained at cathode potential. From this narrow gas discharge strip struck to the relevant row, the column electrodes 4 provides for the control of individual image points, to direct electrons through individual holes 2, in the perforation martix 1, either successively along a row, or simultaneously through all the holes of a row, depending upon whether the signal is applied sequentially in direct manner, or fed via intermediate stores, arranged as a series shift register, so that control can be effected simultaneously for the whole row of individual image point conductor paths, electrons passing only if the relevant control signal has a corresponding postive value. Despite the high positive field strength, in this discharge space no glow discharge is struck because the discharge space is narrow enough to correspond with the conditions governing the Paschen discharge characteristic.

With switching to the next row, the latter then strikes, its ignition being facilitated by the residual ionisation of the preceding row, which perists after the latter has extinguished. The gas discharge thus steps along from row to row, and remains confined to this gas discharge space. The control electrode structure 4 arranged at the other side of the perforation matrix and likewise subdivided into parallel elements, thus functions as individual control grids for the associated holes, controlling the intensity of the electron beam current drawn from the gas discharge by the high voltage on the screen electrode. If the control electrode is negatively biased relative to the auxiliary anode 3, which is substantially at earth potential, then any electron flow is blocked.

As those skilled in the art will realise, in accordance with the Paschen Law set out in Figure 2, where the discharge voltage is plotted against the product of gas pressure p multiplied by the electrode interval d it is possible for a given gas pressure and electrode spacing to ascertain that voltage below which ignition cannot be initiated, i.e. where no glow discharge is possible. Below a minimum value of this product, which is characteristic of each individual gas, the discharge voltage rises very steeply, and with it the voltage at which ignition is not possible; and in the case of argon, (not shown) this value is 0.9 mm.Hg.cm at a voltage of 137 V. At a low pressure, of about 1 mm.Hg, and an electrode spacing between the cathode 5 and the auxiliary anode structure 3 of about 1 cm, for example, it is possible to strike and maintain a glow discharge with a potential difference as little as some few hundred volts. In the electron acceleration space between the electrodes 4 and 6, which is separated from the gas discharge space by the perforation matrix 1, because of the much smaller electrode spacing between the control electrode 4 and the screen electrode 6, a much higher voltage, up to several thousand volts, can be applied without causing a discharge to strike. Thus, the striking of a glow discharge is determined for the given values of gas pressure and voltage requirements, by the electrode spacing in any particular embodiment.

The electrons thus produced by the gas discharge act as though emitted from a large-area thermal cathode, and are selectively passed through the holes in the perforation matrix, and because of the high field strength prevailing in the acceleration space and also because of the gas filling, each current flow strikes a specific image point on the screen 6 as a tightly bunched beam without inter-

fering with any neighbouring image point. Thus, by individual control of the electron beams, substantially similar conditions are achieved to those in a normal cathode ray tube. The value of the mean potential, corresponding to a d.c. bias voltage on the control grid, can also be employed to give optimum beam focussing, which is not a difficult problem, in any case, because of the short distance involved. The arrangement described virutally substitutes for a large-area hot cathode. As far as the discharge conditions are concerned, gases such as neon or argon are particularly suitable, because their striking voltage is very much lower than that of air, for example. Also, in the case of argon for instance, any unwanted luminosity phenomenon in the gas itself is negligible.

To drive the image points, e.g. those of a row, the individual signals, in particular video signals, can be applied in chronological sequence to the relevant conductor paths of the control electrode structure 4 so that individual electron streams impinge successively, point by point, on the screen electrode 6, each for a very short period lasting in each case only for as long as the signal persists under the discharge conditions. Because this time is very short, this leads to rather dark images. For that reason, it is advantageous if the signals corresponding to the content of a complete row are previously processed in a buffer store or intermediate store in accordance with the operation of a series shift register in such a fashion that the signals for a complete row are applied simultaneously to the relevant conductor paths. The processing and reorganisation of the relevant video signal to form a signal which is matched to the requirements of the matrix can be effected in a conventional series shift register with a corresponding number of parallel outputs, for example about 800 in the case of a 625 line television picture. In the series shift register, to this end the analogue video signal is shifted point by point until the individual registers, consisting of semi-conductor stores, are all filled.

In order to achieve the maximum possible brilliance in the discharge display device, in practice, considering a monochrome picture, the row electrode structure must exploit the full television line scan period of 64 microseconds fully for storage. The register, however, also requires this amount of time to be filled by the signal elements, so that two such stores may be arranged to operate alternately to process the signals, e.g. one for the even lines and one for the odd lines. Thus, based upon the normal line periodicity of 64 microseconds encountered in television pictures for example, a corresponding brilliance factor can be achieved.

However, if the individual eletcron streams are to persist for a longer period of time, then the video signal must be stored individually in respect of each point. This can be achieved by use of a matrix drive system in which signal input is carried out using a respective three-terminal device, e.g. in then form of a transistor. In this kind of situation for example, an integrated system of 500,000 transistors is required for an area corresponding to that of a television picture screen. This problem is one which at the present day can be resolved only by the use of a thin-film technique, employing field-effect transistors, for example.

An arrangement of such transistors in a discharge device is shown schematically in Figure 3. A grid for controlling the flow of electrons is formed by a respective metal rim 14 around individual square holes 12 in an insulated perforation matrix 11. On the top face of the perforation matrix the matrix wiring is arranged, which consists of row electrodes 17, which form respective source electrodes, the row electrodes being intersected by column electrodes 18 which have short stubs 19 extending to serve as gate electrodes for the respective transistors. The individual control electrodes 14 serve as the respective drain electrodes of individual field-effect transistors 21, and are not interconnected. Each electrode 14 co-operates with a metallic layer 13 serving as an anode eletcrode on the under-surface of the illustrated plate 11 to form individual storage capacitors. The entire area thus processed is finally coated with an insulating protective layer for security reasons, to prevent any deterioration of the transistors.

When using sequential drive techniques, operating point by point, with individual storage for each point, a video signal V or a signal processed in a series shift register is applied to the individual conductor paths 18. To record a single row, a potential which is positive relative to the cathode is applied to one of the horizontally extending conductor paths 17. Because the control electrodes 14 are initially at earth potential or at a negative potential, then depending upon the potential on the particular conductor path 17 and its associated gate electrodes, currents of varying intensity flow to charge up the capacitors formed by the individual control electrodes 14 to a positive potential peak. This potential peak then controls the actual electron flow from the auxiliary gas discharge space to the screen electrode, thus switching in each individual electron beam with the desired intensity. This electron stream continues to flow as long as the control electrode 14 is sufficiently positively charged.

During this control operation, each capacitor formed between an electrode 14 and the auxiliary anode 13 is charged up. Ac-

cordingly, it serves as an individual store relative to the associated electron beam. Its charge, and therefore its control voltage, can be assumed to reduce in a predetermined manner due to leakage currents, but if such currents prove to be too weak, a vaporised-on resistive layer may be provided between the electrodes 14 and 13 to serve as a shunt in each case, and to ensure that a determinate time constant is produced. Should the leakage currents be too heavy, in any particular embodiment, then they can be reduced by increasing the size of the holes 12 that are formed in the perforation matrix 11, so that the control grids, 14 have enlarged opening relative to the openings in the earthed auxiliary anode 13 at the back of the perforation matrix.

By arranging an advance of the constant voltage applied to the conductor paths 17, one row after another is then recorded in the same way.

By the advancing of the gate contacts 19 it is arranged that the video signal is driven in a point by point sequence. However, it is better to use the known procedure described earlier, in which the video signal is stored in a buffer store or intermediate store, so that it is prepared in accordance with the operation of a series shift register and in each case the signal for a complete row simultaneously applied to the lines 18. A prime advantage of this method is that the picture or image exhibits less flicker, and time is gained for the charging up of all the capacitors formed at intersection points 20 via the conductors 17 to the full video signal value. If, for this purpose, the entire time interval available for the individual row is taken up, for example 64 microseconds in the case of television pictures, then an adequately bright image can be achieved.

A similar system is also suitable for cases in which it is not a moving image which has to be reproduced, but in this case, the storage capacity should be made particularly large and the leakage current from the control electrode particularly small.

The arrangement described can be adapted to display coloured images. For this purpose, three times the number of source and gate conductor paths is needed, and in order to achieve the smallest possible switching capacitance, it is advantageous to increase the number of row conductor paths. In this context, the individual colour components must also be so produced that they can be applied simultaneously in respect of each colour row. Of course this means that for each individual colour row, only a third of the time, i.e. only 21 microseconds, is now available. A weak video signal on the transistors can be compensated for in some cases by the use of a higher beam intensity, or by a longer storage time, e.g. longer than 1/10 of the particular field scan period.

WHAT WE CLAIM IS:—

1. A luminous discharge display device in which a gas-filled sealed envelope contains a common flat cathode, a luminescent screen electrode, and an insulating plate located between, and parallel to, said common cathode and said screen electrode and having a regular array of perforations forming individual image points of a gas discharge cell matrix, said plate serving as a carrier for two excitation electrode structures, one being an auxiliary anode structure, and said cathode and said auxiliary anode electrode structure being on one side of said plate and mutually spaced at a distance adequate to permit normal glow discharge conditions for the particular gas and pressure, the electrode formed on or carried by the other side of the plate being control electrode structure forming individual elements each associated with a respective one, or a respective group, of said perforations, said luminescent screen electrode being spaced from said control electrode structure by a distance significantly less than that between said cathode and auxiliary anode structure.

2. A display device as claimed in Claim 1, in which said perforated plate is made of glass, ceramic or a synthetic resin material having an adequately low vapour pressure, which divides the gas discharge space into an auxiliary discharge space from which the gas discharge electrons penetrate via the perforations in respective collimated beams.

3. A display device as claimed in Claim 2, in which said perforated plate carries a set of mutually separate, parallel conductor paths arranged on each face, the conductor paths on one face constituting said auxiliary anode structure and being perpendicular to those on the other face, which constitute said control electrode structure.

4. A display device as claimed in Claim 3, for generating multi-colour displays, wherein triple conductor paths are provided in one of the two sets.

5. A display device as claimed in Claim 4 in which, said conductor paths are manufactured by printing, vapour-deposition or photographic processes, and wherein the paths divide at the perforations to pass around the peripheries of the latter.

6. A display device as claimed in Claim 4, in which each set of conductor paths consists of parallel wires.

7. A display device as claimed in any preceding Claim in which the distance between said common flat cathode and said auxiliary anode structure is approximately 1

cm, and the distance between said screen electrode and said control electrode structure is significantly less than 1 cm.

8. A display device as claimed in any preceding Claim, in which the transmission coefficient of said matrix is better than 20%.

9. A display device as claimed in any preceding Claim, in which the number of perforations is 5×10^5, the device being for monochrome television display.

10. A display device as claimed in any one of Claims 1 to 8, in which the number of perforations is 1.5×10^6, the device being for colour television display.

11. A device as claimed in any of Claims 3 to 6, in combination with means for applying a constant potential of several hundred volts, relative to the cathode potential, in succession to the individual conductor paths constituting the auxiliary anode structure, said screen electrode being maintained at a constant positive potential of several thousand volts relative to the cathode potential, and means for applying to the control electrode structure a d.c. bias voltage together with a selectively applied control signal with the help of intermediate store, said control voltages being applied in succession to the individual conductor paths constituting the control electrode structure.

12. A display device as claimed in Claim 1 or Claim 2, in which said auxiliary anode structure has elements electrically connected together to form a substantially continuous electrode surface, and said control electrode structure is constituted by two sets of mutually perpendicular intersecting parallel conductor paths, which are equal in number and insulated from one another.

13. A display device as claimed in Claim 12, in which a planar transistor is formed by the provision of semiconductor material at each perforation, each conductor path of one of said sets serving as a source electrode for its associated transistors, each conductor path of the other of said sets serving as a gate electrode for its associated transistors, and insulated metal rims being provided around each perforation to serve as a drain electrode for each transistor.

14. A display device as claimed in Claim 13, in which said semiconductor material is a vapour-deposited material.

15. A display device as claimed in Claim 14, in which said semiconductor material is CdS, CdSe, ZnS or Te.

16. A display device as claimed in any one of Claims 13 to 15, in which said transistors are covered by an insulating protective layer.

17. A luminous discharge display device substantially as described with reference to Figure 1 or Figure 3.

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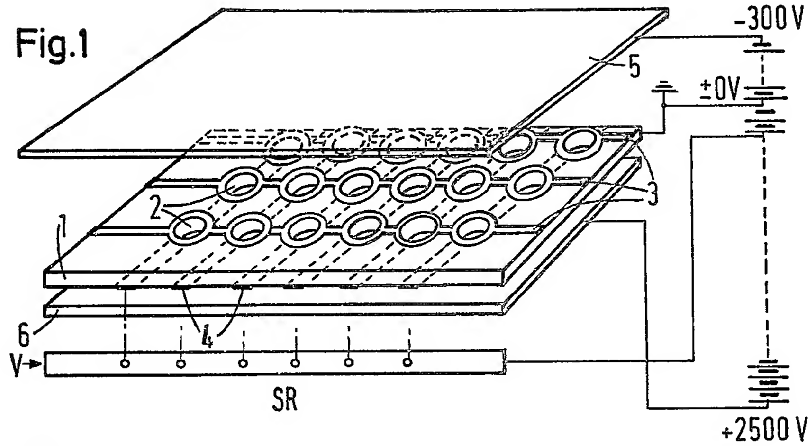
1496442 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

Fig.1



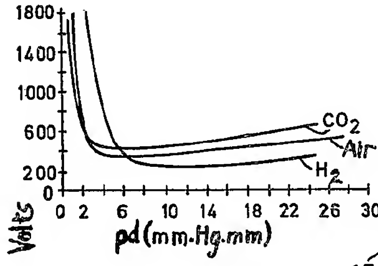


Fig.2

Fig.3